

## HISTORICAL DATA ON THE VARIATION OF RAINFALL IN CHILE.

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**SYNOPSIS.**—A book published by B. V. Mackenna in 1877 contains numerous researches into the municipal archives at Santiago. These are summarized, and shown to suggest two periodicities in rainfall: 1. A variable "Brückner period." 2. A period of about 108 years. 3. In addition, the eighteenth century was drier than the nineteenth.

## INTRODUCTION.

Recently there has come to my notice an old and apparently little known book, published by B. Vicuña Mackenna at Valparaíso in 1877, and bearing the title "Ensayo Histórico Sobre el Clima del Chile (desde los tiempos prehistóricos hasta el gran temporal de Julio de 1877)". The author appears to have brought to bear a good deal of research into the municipal archives at Santiago and other documents, and in view of the recent work of Prof. Ellsworth Huntington his results are of interest.

Many of the 476 pages which form the book are occupied by accounts of the systems of irrigation in Chile and by the speculative meteorology of the seventies, but the remainder contains much interesting information, which is collected in the following summary:

- 1520. Discovery of Chile. A drier year than 1536.
- 1536. Very hot spring and stormy summer, followed by a period of calm and abundance.
- 1540. Pedro de Valdivia traversed the desert of Atacama with a column of troops and cattle without inconvenience. This period of rain continued till 1544.
- 1544. Heavy rains and storms in June. "a monstrous thing." "The Indians say that they have never seen any such thing, but have heard from their fathers that in the time of their grandfathers was such another year."
- 1609. A real flood like that of 1544. Jines de Lillo commenced building river walls.
- 1618. The Mapocho overflowed its channel because of the copious rains. And this was in autumn.
- 1637-1640. First historic drought. "In these three years (1637-1639) one could not collect a penny [of rent] for the droughts."
- 1647. Inundation on June 16. The spring was extremely rainy.
- 1650. (circa). In the second half of the seventeenth century was a continuation of the general drought so that in 1637 "one sold farms which had cost 12,000 pesos for only 250 pesos."
- 1682-1692. But a flood of the Mapocho tore down some of the walls between 1682 and 1692.
- 1697. There was a general inundation of the country.
- 1705. July 6. Public prayer for rain.
- 1710. Year of drought.
- 1717. August 6. An act was passed by the corporation of Santiago appointing a water sheriff, to divide the waters of the Mapocho fairly according to area of land. In the same year was first mooted the diverting into the Mapocho of the neighboring river Maipo.
- 1718. March 6. Another public prayer for rain. The scarcity of water was prolonged until 1722.
- 1723. And was followed by a flood in 1723.
- 1727. Year of drought.
- 1730. Great earthquake.
- 1743. Great drought; prayers for rain.
- 1744. Slight flood and epidemic.
- 1746. Copious rains.
- 1748. Great flood (the worst of the eighteenth century except that of 1783). This flood destroyed the river walls of Jines de Lillo (1609) and a bridge of 60 arches built in 1670-1682. The city was completely inundated.
- 1749. New river walls were commenced.
- 1751. Terrible earthquake. (The heavy rains appear to have continued until 1761.)
- 1764. Flood of Gonzaga.
- 1770. Rained only 112 hours.
- 1771. A still greater drought. A special meeting of the municipal council ordered prayers for rain.
- 1772-73. Drought still continued, especially in 1773.
- 1774. One of the driest years of the century.
- 1775-77. Continued dry.

- 1777. June 25. Public prayer for rain ordered. This year was "a veritable furnace."
- 1779. Agitation to divert waters of River Colorado into Mapocho. May 13. Serious flood inundated the lower part of the city and attacked the walls commenced in 1767.
- 1781. But save for this flood the drought was prolonged into 1781.
- 1782. May 2. A prayer for rain was ordered, because there was no water for the vineyards.
- 1783. April 13. The great flood set in. A heavy trembling, followed by a series of shocks during most of April. May was excessively rainy. On June 3 was an alarming flood of the Mapocho. From June 3 it continued to rain violently and on morning of 16th were completed 209 hours of incessant rain, accompanied by a hurricane from N. On 17th the rain ceased and the flood began to subside.
- 1784. The drought again set in. The deficiency of water lasted at least until 1791. (Public prayer for rain on June 7.)
- 1791. Year of drought.
- 1797. Fields extremely sterile.
- 1799. Year of drought.
- 1804-1824. Moderate years with a tendency to scarcity rather than excess of water. 1804 was the driest.
- 1812. The spring of 1812 was probably stormy, as the barometer reached a very low level.
- 1817. Was excessively rainy in the south and center of the country. The armies in the War of Independence could not make way for the floods.
- 1819. Was sterile. Up to June 2 no rain had fallen in the capital. After that till 1822 there was excess of rain.
- 1822. The spring of 1822 was wet.
- 1823 and 1824 had comparatively dry springs.

The total of days and hours in the following table are taken from a book, probably by Tomas Reyes:

Year.	Days.	Hours.	Notes.
1824	10	220	There were some very heavy falls.
1825	21	130	The falls were less heavy.
1826	17	147	Year of slight rain; one very heavy fall.
1827	31	300	One of the wettest years of the century. First shower on April 17. Heavy rains began on June 1. On the night of June 5 the barometer reached its lowest since 1812 and a great flood burst over the north part of the city, but this flood was not comparable with that of 1783. At the same time took place the greatest flood known on the Serena till then.
1828	30	280	} Almost as rainy as 1827.
1829	31	320	
1830	17	116	Heavy shower of 10 hours on January 30.
1831	13	150	} A year of plagues and mortality. On August 12 snow fell heavily. Wettest year but one of the series. First shower on April 14.
1832	-----	99	
1833	-----	440	Flood on Mapocho in July.
1834	19	152	} First showers in January. Flood on Mapocho in May.
1835	16	118	
1836	-----	219	} Comparatively dry.
1837	-----	288	
1838	-----	156	} Rain commenced on February 21.
1839	-----	125	
1840	-----	153	} But heavy rain. A fall of 3 hours in January, then on June 8-11.
1841	-----	313	
1842	-----	171	} Short shower in January.
1843	41	390	
1844	-----	130	} Excessively wet, though there were comparatively few rainy days.
1845	-----	417	
1846	-----	240	} Alarmingly dry. Great snowfall at Santiago on August 18. Short shower in January.
1847	29	147	
1848	-----	111	} First shower on March 30. One of the stormiest springs known; great heats, gales, and floods, especially in June; 553 mm. of rain fell at the American Observatory established under Domeyko at Sta. Lucia. This was the last year of observation by days, hours, and minutes.
1849	13	185	
1850	41	285	

The average for the whole period was 20 days 215 hours.

- 1851. Very wet, especially at Coquimbo. The series of wet years lasted till 1860.
- 1856. Hurricane from North on March 11-13, causing floods in the Serena and Mapocho. At Concepcion the hurricane appeared on the 9th.
- 1858. Flood.
- 1863. Very dry and hot. No rain till June 1 and then only a little.
- 1864. Very stormy. Hurricane in Valparaíso on June 2 to 9. Flood on the Mapocho.

1868. Flood.

1876. A planter kept count of the rain days and hours "as of old." The duration was 26 days and 187 hours. The corresponding rainfall was 215 mm.

1877. Rain began in February (0.38 inch on 9th at Valparaiso). Heavy rain in April; 3 inches in a heavy gale on 25th. May and June were mild, but very heavy rain in July caused floods on all the rivers of Central Chile.

#### Summing up, the author finds:

1. The climate of Chile is essentially stable.
2. Droughts have occurred at intervals from prehistoric times.
3. Periods of drought were much more prolonged formerly, especially in the eighteenth century, when they sometimes lasted 20 or 30 years, (1705-1723 and 1770-1797); and there were frequent years calamitous for public health and agriculture (1705, 1710, 1717, 1727, 1743, 1770, 1771, 1773, 1777, 1781, 1782, 1784, 1791, 1797, 1799). In the nineteenth century only two years were comparable with these (1832 and 1863).
4. Floods have occurred with a similar periodicity, but much further apart, and sometimes in the middle of a period of drought which they did not seriously modify. They were more frequent in the nineteenth century than in the eighteenth.
5. The rainy years occur almost always in groups, forming more or less long and homogeneous periods of three, five or more years.

#### To these conclusions I would add:

6. If we tabulate the data we find evidence of a remarkable double periodicity. Taking the wet periods first as being more sharply defined and completing the series from the readings of the rain gage at Santiago, we have:

	1536-1544	No records.
1609, 1618	1647	1692, 1697
1723	1744-1768	1779-1783
1827-1830	1850-1877	1898-1907

Between 1544 and 1609 there are no climatic data at all, but if we assume that this interval of 66 years was broken by a slight maximum of rainfall in the middle, we have from 1540 to 1904 the crests of 11 waves of rainfall, separated by 10 depressions, giving an average interval of 36 years, which agrees well with Brückner's period. The individual intervals were, in years:

(?) 37, (?) 37, 34, 48, 28, 33, 26, 48, 34, 40.

Further, the middle years of each century appear to have represented the maxima of a major wave of about 108 years (the intervals are 107, 109, 107 years), which agrees closely with periods of between 106 and 111 years advocated by various authors. There is evidence that this period goes back yet another cycle, in the statement referred to 1544; that a similar flood was experienced three generations earlier.

The chief periods of drought show a similar periodicity, but less marked:

	1637-1640	1650-1687
1705-1722	1743—	1770-1777
1784-1804	1831-1832	1879-1880
1909-1912		

#### RAINFALL VARIATIONS.

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At the meeting of the Royal Meteorological Society held on April 16, two papers on variations of rainfall were read.<sup>1</sup> The papers are summarized below.

Mr. A. A. Barnes, in his paper on "Rainfall in England, the true long-average as deduced from symmetry,"<sup>2</sup> stated that it has been usual to assume that the average annual rainfall during any period of 35 years can be adopted for obtaining the "long-average" at any rain gage, but he considers that the fluctuations which occur between such averages for various 35-year periods tend to show that the basis is somewhat uncertain. By an exhaustive analysis of the annual readings at 38 rain gages in England during the 62 years 1856-1917, he shows that variations of as much as 5 per cent. on each side of the mean are quite possible when dealing with successive 35-year periods. From these same records it is then shown that far greater consistency in the value of the average can be obtained by taking periods symmetrical about the end of the year 1886. Both by means of tables and diagrams Mr. Barnes shows that that date is a very critical one in regard to rainfall in England, and that, as a rule, the years before that date were relatively far wetter than years subsequent to it. Hence the balancing of the earlier wet years by the later dry years establishes the principle of symmetry about that date, and it is shown that by this method the maximum departure from normal which results from taking each of the fifteen long periods symmetrical to the end of the year 1886 does not exceed 1 per cent in the case of any of the 38 gages which were examined.

Mr. C. E. P. Brooks's paper was on "The secular variation of rainfall."<sup>3</sup> In order to obtain a measure of the secular variation of rainfall during the past 30 to 50 years, correlation coefficients were worked out between the annual rainfall at each station and "time," the measure of the latter being the number of years before or after the middle year of the series. This was done for 162 stations distributed over the globe, and the results were charted on a map. This map shows that the greater part of the world is divided among a few definite regions of wide extent, in each of which the rainfall has been either increasing or decreasing. The most important area of increasing rainfall is temperate Eurasia (except the western seaboard); other areas are southeast South America and the south of Australia. Areas of decrease are the tropical regions as a whole, South Africa, and the west coast of Europe. It is noted that the number of sun-spots, and also that of solar prominences, during the period in question have been decreasing. For a few stations records of longer period are dealt with, giving indications that the results obtained are due to a periodicity of upwards of 50 years.

<sup>1</sup> See *Quart. Jour. Roy. Meteorological Soc.*, July, 1919, vol. 45, pp. 209-227, discussion, pp. 227-232. Abstract in *Sci. Abs.* Sept. 30, 1919, pp. 418-419.

<sup>2</sup> *Idem.*, pp. 209-232.

<sup>3</sup> *Idem.*, pp. 233-248.